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"Radar handbook" by M. I. Skolnik (McGraw-Hill 1970): pp 21-10 to 21-17 (especially figs. 14, 21).

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(71) Applicant
The General Electric Company Plc

(Incorporated in the United Kingdom)

1 Stanhope Gate, London, W1A 1EH, United Kingdom

(72) Inventor
John Richard Wallington

(74) Agent and/or Address for Service
Colin F Hoste
The General Electric Company plc, Central Patent Dept, Marconi Research Centre, Great Baddow, Chelmsford, Essex, United Kingdom

(54) **Receiving system**

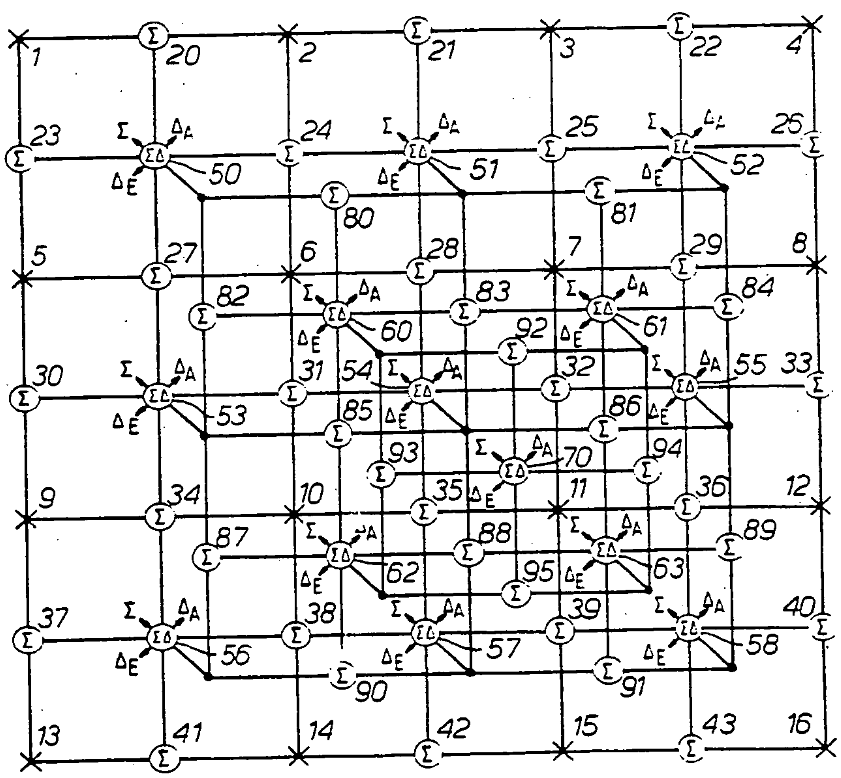
(57) A receiving system uses an array of separate antennas each of which covers a small angle of space. Groups of antennas are connected in a hierarchy so that together they cover a wide angle of space. When a target is passed over from one group e.g. 1, 2, 5, 6 to another e.g. 6, 7, 10 & 11 the current group is transformed into a larger group, e.g. 1, 2, 3, 5, 6, 7, 9, 11 embracing the group into which the target will pass. Thus a moving body can be tracked across space covered by different antennas, or sub-groups of antennas without introducing control discontinuities which could result in loss of target.

× DIPOLE, MIXER, AMPLIFIER

Σ SUM AMPLIFIER

ΣΔ SUM/DIFFERENCE AMPLIFIER

FIG. 1.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

GB 2 227 886 A

× DIPOLE, MIXER, AMPLIFIER

(Σ) SUM AMPLIFIER

(ΣΔ) SUM/DIFFERENCE AMPLIFIER

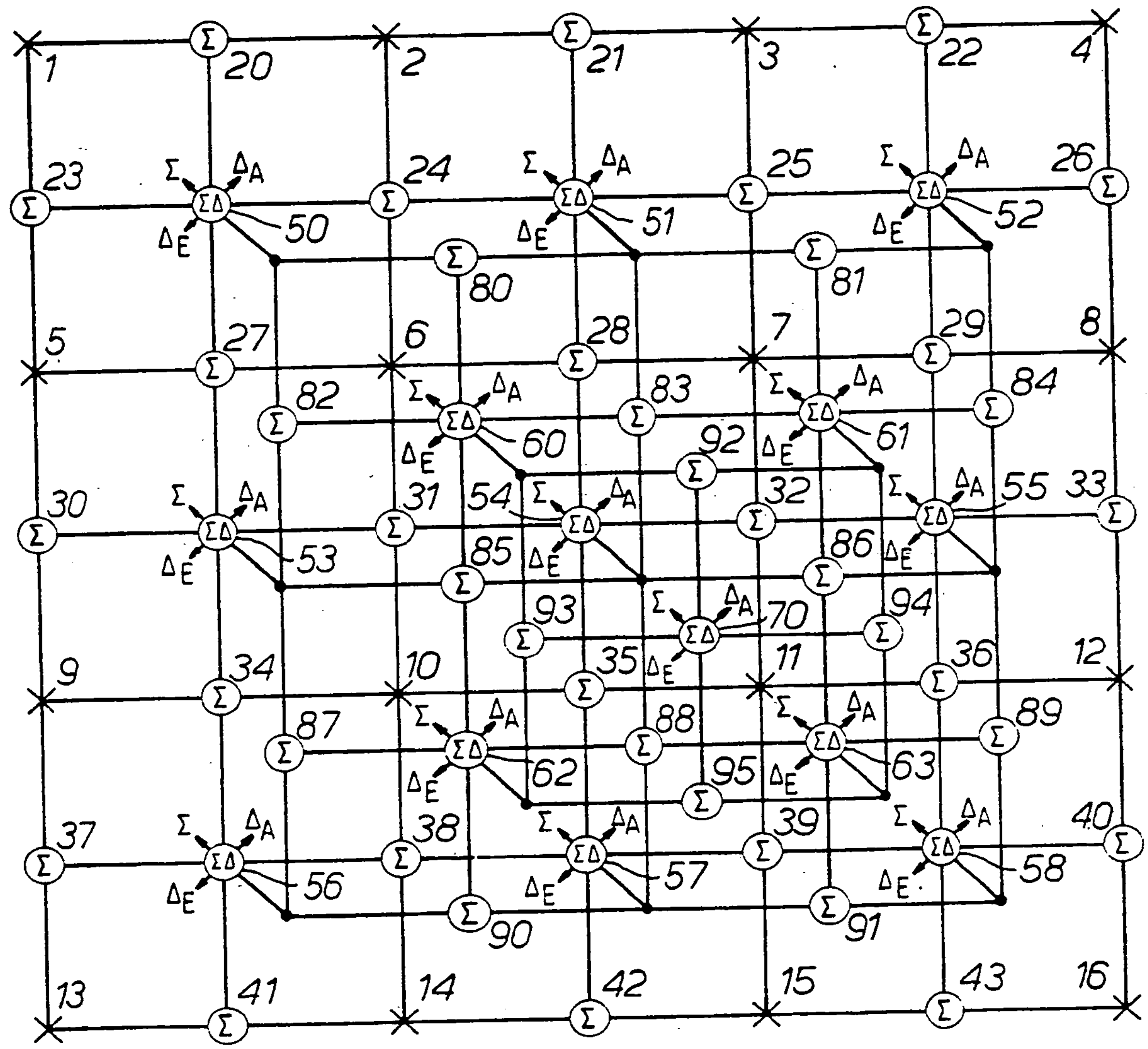


FIG. 1.

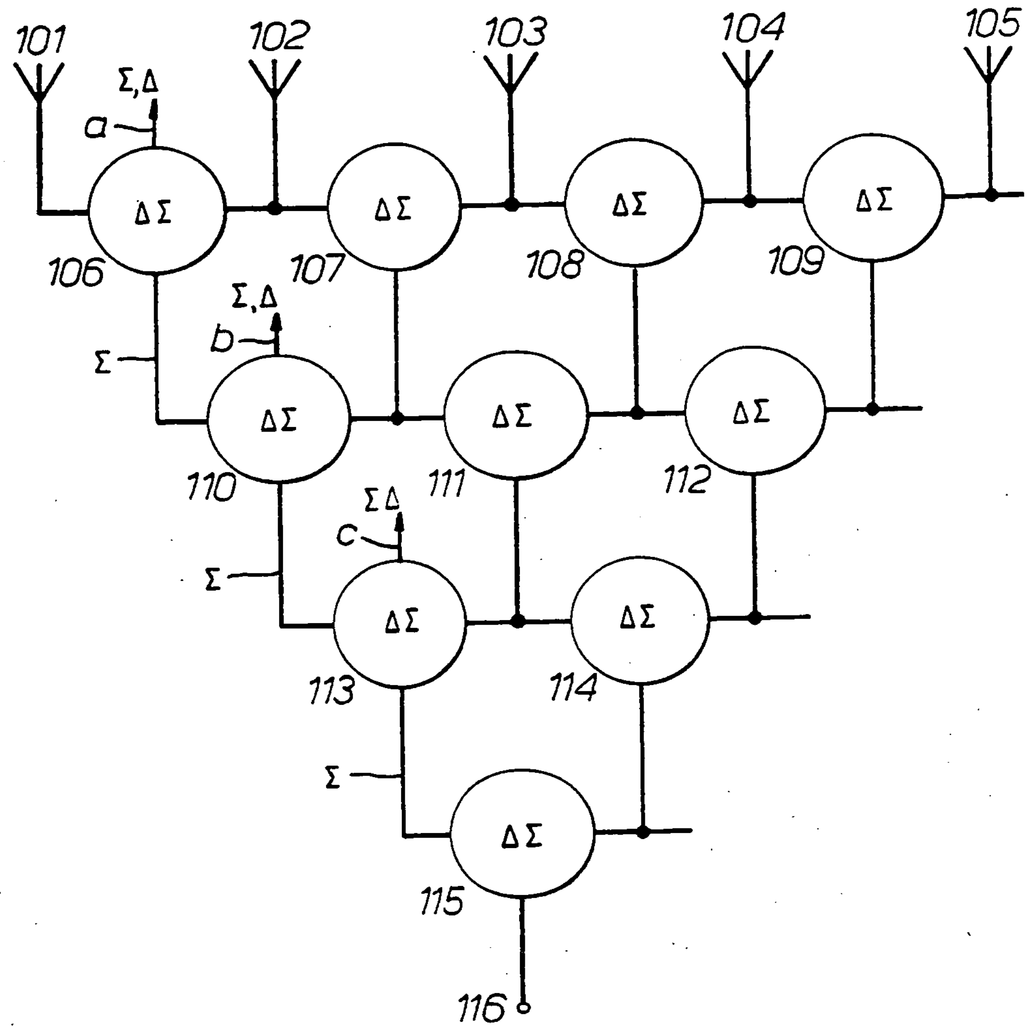

101
102
103
104
105
Σ,Δ
a
ΔΣ
106
107
108
109
Σ,Δ
b
Σ
110
111
112
ΣΔ
c
Σ
113
114
Σ
115
116

FIG. 2.

3/3

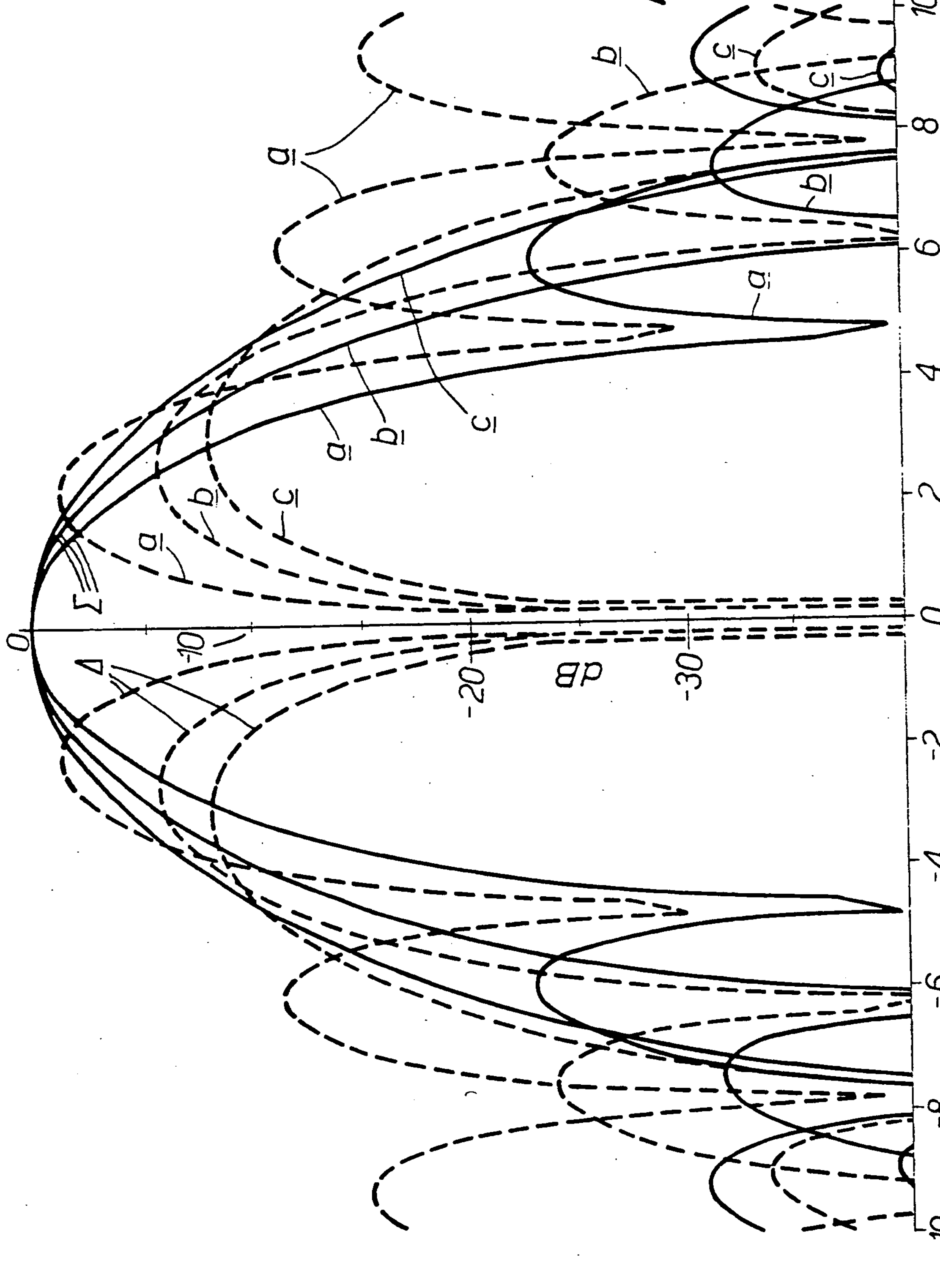


FIG. 3.

Receiving System

This invention relates to receiving systems, and is concerned with systems in which a large number of receiving antennas are mounted in close proximity to each other, so that together they have a receiving pattern which extends over a wide solid angle of space. The antennas can be notionally arranged in small groups, each group of which relates to signals received from a particular small solid angle of space. If the receiving system is used to track a moving body, or is receiving signals from a moving body, difficulties arise when the body moves from a region of space covered by one group of antennas into an adjacent region covered by a different set, and significant and serious signal discontinuities and disturbances can arise, which could possibly result in loss of a tracked target.

The present invention seeks to provide an improved signal receiving system which is arranged for the reception of high frequency signals.

According to a first aspect of this invention, a high frequency receiving system includes a plurality of individual receiving antennas arranged in an array, the antennas being organised into groups in which a given antenna can form part of more than one group, with the members of a group being interconnected so as to be operable in sum and different modes; means for interconnecting a plurality of groups to form a larger set, the constituent groups of which are arranged to present input signals to said larger set which itself is operable in sum and difference modes.

The array may be linear, or it may be planar, in which latter case, conveniently each group consists of four antennas. The planar array may be flat,

i.e. confined to two dimensions, or the plane in which they lie may be curved. The individual antennas are preferably aligned into what can conveniently be termed rows and columns to form a regular matrix array in which the antennas are equally spaced apart from each other.

According to a second aspect of this invention a high frequency receiving system includes a plurality of receiving antennas arranged in a planar array consisting of a plurality of first order groups each consisting of four antennas interconnected so as to be operable in sum and difference modes; the groups being organised into a plurality of second order groups, with each second order group comprising four first order groups each arranged to present input signals to the second order group of which they form a part so that it is operable in sum and difference modes.

Each individual antenna has a relatively narrow receiving beam profile and the beams of all antennas together represent coverage of a wide angle solid cone of space.

Additional higher order groups, i.e. third and fourth order groups, can be provided if desired depending on the number of individual antennas and the way in which they are configured.

Thus, if there are sixteen antennas arranged in a regular two dimensional four-by-four array, i.e. four "rows" and four "columns" with an antenna at each crossing point, this comprises a pattern of nine first order groups and four (two-by-two) second order groups which in turn are interconnected to form a single third order group.

The invention is further described by way of example with reference to the accompanying drawings, in which:

Figure 1 illustrates a configuration for a network consisting of sixteen dipole antennas.

Figure 2 is a diagram relating to a linear array of antennas, and

Figure 3 is an explanatory diagram relating to Figure 2.

Referring to Figure 1 a regular matrix of sixteen dipole antennas 1 to 16 is organised as a regular four-by-four array to form part of a high frequency receiving system. Each antenna is a receiving dipole which can conveniently form part of a beam-forming structure with the beam forming a constituent part of the reception pattern of the system. The dipole antenna array is positioned in the focal plane of the beam-forming structure.

Each dipole antenna conveniently incorporates a mixer to convert the received signal to a lower intermediate frequency, and also an amplifier to boost the level of weak signals. Adjacent dipole antennas are connected to a common amplifier. In the array illustrated in the drawing, it is necessary to provide twenty-four separate sum amplifiers, numbers 20 to 43 inclusive.

The sixteen dipole antennas 1 to 16 can be regarded as consisting of nine groups of dipole antennas, each consisting of just four dipole antennas, e.g. dipole antennas 1, 2, 5 and 6 form a single group, and it will be noted that each group of four antennas comprises an identical number of sum amplifiers, and that in general an antenna forms part of more than a single group, e.g. dipole 6 forms part of four different groups. Thus the first group referred to includes sum amplifiers 20, 23, 24 and 27. There are thus nine groups of sum amplifiers, bearing in mind that a particular sum amplifier can be shared by two or more groups in the same way in which antenna 6 forms part of four separate groups. Each

group of four sum amplifiers feeds into a respective one of nine sum and difference amplifier 50 to 58 inclusive. These sum and difference amplifiers are arranged so as to be able to simultaneously provide a sum signal Σ, and difference signals Δ_A and Δ_E, the Δ_A signal representing a difference azimuth signal and the Δ_E signal representing a difference elevation signal. The sum and difference amplifiers are arranged so as to operate both in sum and difference modes at the same time. Thus, conventional sum and difference signals can be achieved by means of this network. Whether a Δ_A signal or a Δ_E signal is obtained depends on which output port of the sum and difference amplifier is utilised.

Each of the nine separate groups of dipole antennas can be operated in an independent sum and difference mode so as to produce a single sum signal and two separate difference signals. Each group is, in practice, mounted so as to cover a different solid angle (or "cone") of space and can detect targets located within that area. The actual position, and hence movement, of the target can be determined in conventional manner by noting the magnitude and phase of the difference signals obtained. As each group covers a relatively small angle of space the position of a target can be determined to a high degree of accuracy whilst it is within that sector. However, in practice, a target is likely to move from one sector of space to another and the interface noise, and discontinuities in the processed signals which occur as a target is handed over from one group to another can be severe, and can under extreme circumstances result in loss of target. Alternatively, hand-over may occur during a particularly critical period of operation.

When a target is to be handed over from one small

group of antennas to another, that group in which it is currently positioned is transformed into a larger group which also includes the group to which the target will pass. Thus, if a target is initially being tracked by the first order group of four antennas, 1, 2, 5 and 6,that group is notionally expanded into a larger second order group consisting of nine antennas, 1, 2, 3, 5, 6, 7, 9, 10 , 11, and the outputs of the four associated sum and difference amplifiers 50, 51, 53 and 54 are treated exactly as though the sum and difference amplifiers were in fact acting as individual receiving antennas. In this way the second order group consisting of the nine antennas is able to generate the sum and difference signals for the second order group as a whole. As the smaller first order group consisting of only four dipoles forms a sub-set of the new group, hand-over to the new group can be achieved smoothly and without disturbance. If desired, control can subsequently be handed over to another first order group lying wholly within the second order group, i.e. reception can be passed to the group of four dipoles 6, 7, 10 and 11 if required.

In practice, a different mode of operation may be more advantageous. Initially, all sixteen dipole antennas can be connected to form a single third order group having a single sum and difference amplifier 70 from which the output signals are obtained. In this case all of the sum and difference amplifiers 50, 51, 52, 53, 54, 55, 56, 57, 58 are organised to constitute the input signals for the four second order groups each having sum and difference amplifiers 60, 61, 62 and 63 which are fed by sum amplifiers 80 to 91. These sum and difference amplifiers are, in turn, connected to a similar array of sum amplifiers 92 to 95 so as to feed a single sum and difference amplifier 70.

Thus by correctly organising the individual sum amplifiers in the total array of sixteen antennas, the outputs of the sum and difference amplifier 70 represents a single sum signal Σ for the array as a whole; a difference azimuth signal Δ_A and a difference elevation signal Δ_E. These signals represent information relating to the solid cone of space which is covered by all sixteen antennas. This configuration is particularly useful when the dipole array is required to cover a very large solid angle of space. This situation can apply prior to the acquisition or detection of a possible target whose initial position is not known. Once a target has been detected, it is tracked by the whole antenna dipole array, and by using a prediction of its movement a particular second order group, e.g. dipoles 1, 2, 3, 5, 6, 7, 9, 10 and 11 can be selected from the four possible second order groups.

Movement within this more restricted area is then monitored using only the designated second order array of nine dipoles. This gives a higher degree of accuracy, since any associated signal processors are considering a smaller solid angle of space. Ultimately, as the target continues to move into a particular first order group, the controls can be handed over from the nine dipoles which comprise the second order group to the appropriate first order group consisting of only four dipoles. This enables a moving target to be tracked with a very high degree of accuracy during the final stages of a tracking operation.

Figures 2 and 3 relate to a linear array of antennas, comprising only five antennas 101 to 105, but more can be added as necessary. Figure 3 shows the resulting beam profiles for the sum signals Σ and the difference signal Δ, it being easier to

represent these profiles diagramatically for a linear array. The difference signal can relate to elevation,azimuth or some other plane.

In a manner which is analogous to Figure 1, the antennas are connected via cascaded sum and difference amplifiers 106 to 115, to an output port 116 at which the two final output signals Σ,Δ for the array as a whole are obtained.

The output from amplifier 106 at terminal 117 consists of the signals Σ, Δ for just the two antennas 101 and 102, and the signals are indicated by the a lines in Figure 3 - the difference signals are represented by broken lines and the sum signals by solid lines. Similarly the output of amplifier 110 is represented by the b lines in Figure 3 and that of amplifier 113 by the c lines. Thus the beam width, and angular cover is dependent on the number of antennas whose outputs are combined.

The necessary control of the dipole antenna array, the sum amplifiers and the sum and difference amplifiers, can be achieved by using simple control networks whose mode of operation follows directly from the preceding description.

Although the antenna array may be mounted on a ground station so as to be fixed in relation to the earth and to cover a predetermined area of space, this need not be the case. Alternatively, the antenna array can be mounted on board an aircraft or missile and can be used to track another body moving in relation to it. Although the invention has been particularly described with reference to dipole antennas, any other convenient form of antenna can be used, e.g. very small horn antennas. The invention is applicable to a starring array of antennas which cover pre-determined solid angles of space with respect to the support on which they are mounted,

and this distinguishes the invention from receiving systems in which a receiving pattern or beam is steered electronically or mechanically to cover any desired angle of space.

Thus in the present invention a large number of pre-determined beam profiles are available, each pointing in a different direction of space, and that beam which is most appropriate to the current circumstances is selected for use. By choosing different numbers of antennas to contribute to the information being processed, i.e. by selecting a group of the appropriate order, the beam profile can be altered so as to give a controlled beam width.

Claims:

1. A high frequency receiving system including a plurality of individual receiving antennas arranged in an array, the antennas being organised into groups in which a given antenna can form part of more than one group, with the members of a group being interconnected so as to be operable in sum and difference modes; means for interconnecting a plurality of groups to form a larger set, the constituent groups of which are arranged to present input signals to said larger set which itself is operable in sum and difference modes.

2. A system as claimed in claim 1 and wherein the array consists of a single line of elements.

3. A system as claimed in claim 1 and wherein the array is two-dimensional.

4. A system as claimed in claim 3 and wherein each group consists of four antennas.

5. A system as claimed in claim 3 or 4 and wherein the individual antennas are arranged in a regular matrix array.

6. A high frequency receiving system including a plurality of receiving antennas arranged in a planar array consisting of a plurality of first order groups each consisting of four antennas interconnected so as to be operable in sum and difference modes; the groups being organised into a plurality of second order groups, with each second order group comprising four first order groups each arranged to present input signals to the second order group of which they form a part so that it is operable in sum and difference modes.

7. A system as claimed in claim 6 and wherein each first order group includes four sum amplifiers connected to receive the input from two adjacent inputs.

8. A system as claimed in claim 5, and wherein each

first order group includes a sum and difference amplifier, the nature of its output being dependent on the combination of the associated four sum amplifiers which are arranged to supply inputs to it.

9. A system as claimed in claim 6, 7 or 8 and wherein each second order group includes a further sum and difference amplifier arranged to receive inputs from the four sum and difference amplifiers, which form part of its four constituent first order groups, via four sum amplifiers each of which receives two input signals from said four sum and difference amplifiers.

10. A system as claimed in claims 6 to 9, wherein four second order groups are organised into a third order group arranged to receive inputs from each second order group so as to be operable in sum and difference modes.

11. A high frequency receiving system substantially as illustrated in and described with reference to the accompanying drawings.

Amendments to the claims have been filed as follows

1. A high frequency receiving system including a plurality of receiving antennas arranged in a planar array consisting of a plurality of first order groups each consisting of four antennas interconnected so as to be operable to generate sum and difference signals; the first order groups being organised into a plurality of second order groups, with each second order group comprising four first order groups each arranged to generate a signal derived from the four antennas associated therewith, and each second order group being operable to generate resultant sum and difference signals.

2. A system as claimed in claim 1 and wherein each first order group includes four sum amplifiers each connected to receive the inputs from two adjacent antennas.

3. A system as claimed in claim 2, and wherein each first order group includes a sum and difference amplifier, the nature of its output being dependent on the combination of the associated four sum amplifiers which are arranged to supply inputs to it.

4. A system as claimed in claim 3 and wherein each second order group includes a further sum and difference amplifier arranged to receive inputs from the four sum and difference amplifiers, which form part of its four constituent first order groups, via four sum amplifiers each of which receives two input signals from said four sum and difference amplifiers.

5. A system as claimed in claims 2 or 3 wherein four second order groups are organised into a third order group arranged to receive signals associated with each second order group so that the third order group is operable to generate resultant sum and difference signals.

6. A high frequency receiving system substantially as illustrated in and described with reference to Figure 1 of the accompanying drawings.

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